NOVEL LOW TEMPERATURE SOLID STATE FUEL CELLS

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OBJECTIVES:

The Objective of this research is to fabricate and acquire fundamental understanding of the physical properties and chemical stability of advanced nanostructured materials when used in multilayered structures for the development of an intermediate temperature solid oxide fuel cell (IT-SOFC).

ACCOMPLISHMENTS TO DATE

In the past 15 months, we have fabricated and systematically characterized the highly epitaxial $PrBaCo_2O_5$ (PBCO) thin films for cathodes and multilayered Gd:CeO_2(GCO: Gd:Ce=1:4)/Y:ZrO_2(YSZ: mole 8%) structures in various stoichiometric combinations on (001) MgO substrates for electrolytes. We have demonstrated that the highly epitaxial PBCO films have excellent electrical conductivity. We have also achieved various thickness ratio combinations (10:1, 15:1) of GCO and YSZ and different numbers of stacks (4 layers, 8 layers, etc.) while keeping the same total film thickness. The microstructural studies of the multilayered films were performed with x-ray diffraction (Figure 1(a), in the third report) [at TcSUH] and indicate that the structures are mainly *c*-axis oriented. The crystallinity and interface structures have been examined using cross sectional transmission electron microscopy.

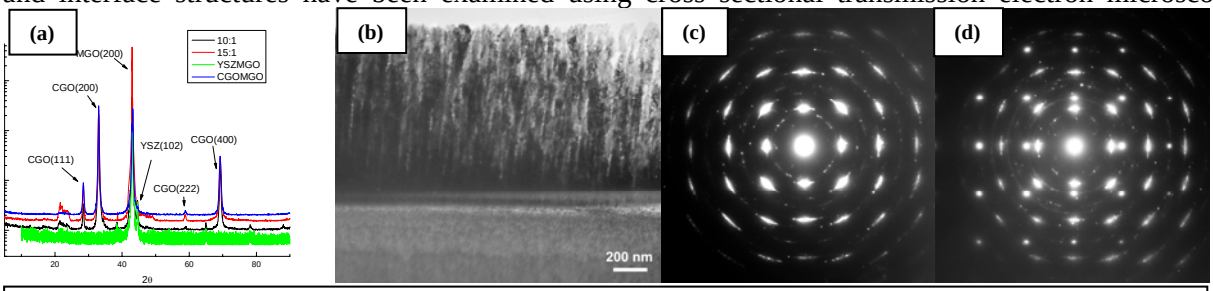

Fig.1. X-ray diffraction and cross sectional transmission electron microscopy studies of the as-grown multilayered structures on (001) MgO substrate. (a) x-ray diffraction scan showing the multilayered GCO/YSZ structures; (b) cross sectional TEM image showing the microstructures of the films, (c) selected area electron diffraction patterns from the multilayered film area showing film has good single crystal quality, and (d) selected area electron diffraction patterns from the interface area showing that the film and substrate have a good interface relationship.

As seen from Fig. 1 (b), the as-grown multilayered YSZ/GCO thin films have good crystalline quality with a columnar structure which is the typical structure for thin films grown with a large lattice misfit. The selected area electron diffractions were taken from the film (Fig.1 (c)) and the film/substrate interface (Fig. 1 (d)), indicating that the as-grown multilayers are good single crystalline with c-axis orientation. The selected area electron diffraction covering the interface area reveals a surprisingly good epitaxial quality and the interface relationship can be determined to be (001)film//(001)MgO and [100]film//[100]MgO, which gives a huge lattice misfit of as large as 22%. The epitaxial nature will be investigated by using the high resolution electron microscopy soon for more detailed information since the current TEM images cannot provide detailed atomic structures in the multilayered film structures and the information about the multilayered interfaces.

The impedance measurements on the multilayered samples with the GCO/YSZ = 10:1 and different numbers of stacks have been accomplished in both pure oxygen (same as the report 3, Fig.2 top) and air (Fig.2 bottom, data are not yet normalized and still waiting for the SEM image to estimate the measurement area) within the temperature range of 600 $^{\circ}$C to 900 $^{\circ}$C, together with the single layered YSZ and GCO for comparison. The detail analysis is on the way and will be completed in the next few weeks. The temperature dependence of the conductivities of the as-grown YSZ/GCO multilayer structures in air is very similar to that in pure O_2 for various numbers of stack (4 layers, 8 layers, 16 layers) but with the same total thickness. More detailed studies are on the way and will be reported later on. The electron leakage in the multilayered structures was found to be smaller than 10^{-5} A/cm^2. Recently, we have also studied the ionic conductive $NdBaCo_2O_5$ thin films for new cathode applications.

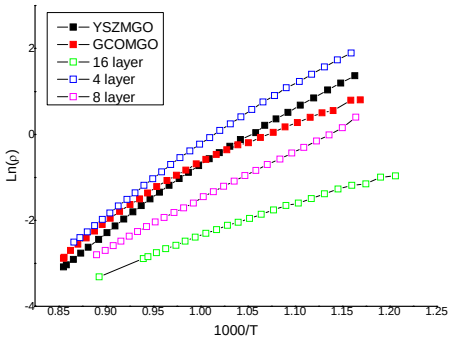

Fig.2. Impedance measurement for the multilayered GCO/YSZ structures with various combinations on (001) MgO in pure oxygen.

FUTURE WORK

We continue to focus on the fabrication and characterizations of mixed conductive PBCO and multilayered ionic conductive GCO and YSZ structures on various substrate materials, and to understand the interface behavior and ionic transport dynamics of oxygen, the systematical investigation of the multilayered GCO and YSZ structures on various substrates. To better understand the interface effect on the physical properties, a high resolution TEM characterization will be performed in the next few weeks. Models for understanding the thickness and interface effects on the ionic transport properties of these multilayered structures are under development. The purpose of the YSZ layer in the multilayered structures is to block the electronic conduction, to enhance the quality of the electrolyte materials and to lower the operation temperature from 800 ^{o}C to 600 ^{o}C. On the other hand, the fabrication and characterizations of half–cell structures from PBCO/YSZ and PBCO/GCO will be the next topic of focus to determine the best interface structures for the cathode/electrolyte interface. We also plan to start the fabrication and characterization of the advanced proton conductive $Y_xBaCe_{1-x}O_3$ (YBCO) for anode use. We will systematically study the physical properties and ionic transport behavior of each material (YBCO, PBCO, and multilayered GCO/YSZ structures). We will fabricate various crystal structures with different crystal grain sizes, and will comprehensively analyze the physical properties and interface phenomena of each material and the effects from interface, size, and strain.

LIST OF PAPER PUBLISHED, US. PATENT/PATENT APPLICATION, CONFERENCE PRESENTATIONS, AWARDS RECEIVED AS A RESULT OF SUPPORTED RESEARCH, STUDENTS SUPPORTED UNDER THIS GRANT

1) Z. Yuan, J. Liu, **C. L. Chen**, C. H. Wang, X. G. Luo, X. H. Chen, G. T. Kim, D. X. Huang, S. S. Wang, A. J. Jacobson, and W. Donner, "Epitaxial Behavior and Transport Properties of $PrBaCo_2O_5$ Thin Films on (001) $SrTiO_3$", ***Appl. Phys. Lett***., **90** (2007) 212111.
2) "Ionic transport properties of multilayered Gd:CeO_2/YSZ structures" to be submitted to Solid State Ionics.
3) Patent disclosure #2008.024.utsa: Multilayered Gd:CeO_2/YSZ structures for intermediate temperature Solid State Fuel Cells.
4) Invited talk: "Multilayered Gd:CeO_2/YSZ structures for intermediate temperature Solid State Fuel Cells", the **MRS International Materials Research Conference**, Chongqin, China, June 9-12, 2008.

SUPPORTS:

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